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ABSTRACT

This document is an instructional module package prepared in objective form for use by an instructor familiar with operation and maintenance of a rotating biological surface (RBS) wastewater treatment system. Included are objectives, instructor guides, student handouts, and transparency masters. This is the third level of a three module series and considers the biology and biochemistry of biochemical oxygen demand (BOD), reduction and nitrification in the RBS process, system applications, process performance and measures to assure proper plant performance. (Author/RH)

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ADVANCED ROTATING BIOLOGICAL SURFACE OPERATION

Training Module 2.122.4.77

Prepared for the

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by

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September, 1977

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TABLE OF CONTENTS

INSTRUCTOR GUIDE

for

Training Module II40WW

Advanced Rotating Biological Surface

Module No: II40WW	Module Title: Advanced Rotating Biological Surface Operation
	Submodule Title:
Approx. Time: 19.0 Hours	Topic: Summary

Objectives: Upon completion of this module, the participant will be able to

1. Cite typical applications of the RBS system and discuss the major features of their application.
2. Fully describe the RBS system and its components.
3. Discuss the biology and biochemistry of BOD reduction and nitrification in the RBS process.
4. Discuss factors that affect process performance and recommended measures to assure the proper performance of the RBS unit.

Instructional Aids:

Slides
Transparencies
Handouts

Instructional Approach:

Discussion

References:

1. Water Pollution Control Federation, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, 1976
2. Autotrol Corporation, Bio-surf Design Manual, 1972
3. Autotrol Corporation, Operating & Maintenance Manual for the Bio-surf Waste Treatment Process
4. Articles from the technical literature

Class Assignments:

Reading from references.
Study of Handouts.
Work sample problems.

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Module No:	Module Title:
II40WW	Advanced Rotating Biological Surface Operation
	Submodule Title:
Approx. Time: 1.5 Hours	Topic: RBS System: Review of Purpose and Components

Objectives: Upon completion of this topic, the participant will be able to
1. Describe and discuss the nature of an RBS wastewater treatment system, its purpose and components.

Instructional Aids:

Slides and transparencies: RBS Unit Schematics
RBS Unit Components

Instructional Approach:

Discussion

References:

1. Water Pollution Control Federation, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, 1976
2. Autotrol Corporation, Bio-surf Design Manual, 1972
3. Autotrol Corporation, Operating & Maintenance Manual for the Bio-surf Waste Treatment Process
4. Articles from the technical literature

Class Assignments:

Study assigned readings in references.
Study handouts.

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Module No: 1140WW	Topic: RBS System: Review of Purpose and Components

Instructor Notes:	Instructor Outline:
Note: Students are likely quite familiar with the system via personal experience and/or previous courses. However, it is important to review the nature of the process. TRANS AD-1 Role of RBS Units TRANS AD-2 Rotating Biological Surface Reactor TRANS AD-3 Typical RBS Configuration TRANS AD-4 Process Unit Components TRANS AD-5 Process Description	1. Discuss the RBS process a. Purpose b. Components and Configurations c. Process performance

Module No:	Module Title:
II40WW	Advanced Rotating Biological Surface Operation
	Submodule Title:
Approx. Time: 3.0 Hours	Topic: Basic Biology & Applications to RBS Unit

Objectives: Upon completion of this topic, the participant will be able to

1. Describe the types of organisms involved in an RBS system and their biochemical characteristics; including heterotrophs and nitrifying bacteria.
2. Discuss the biochemical interactions, e.g. alkalinity destruction in nitrification, organism competition, affect of DO concentration, kinetic factors, denitrification.
3. Describe the types of animal forms and other biota present in the RBS unit.

Instructional Aids:

Transparencies: Biochemical equations of change and synthesis
Bacterial activity under various conditions
Typical organism nomenclature and characteristics

Instructional Approach:

Discussion

References:

1. Water Pollution Control Federation, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, 1976
2. Autotrol Corporation, Bio-surf Design Manual, 1972
3. Autotrol Corporation, Operating & Maintenance Manual for the Bio-surf Waste Treatment Process
4. Articles from the technical literature

Class Assignments:

Study of handout materials.

Module No: II40WW	Topic: Basic Biology & Applications to RBS Unit

Instructor Notes:	Instructor Outline:
TRANS AD-6 Biological Terminology TRANS AD-7 Biological Activity	1. Discuss the biological life in an RBS system a. Aerobic organic conversions and cell growth. Appearance of growth. b. Aerobic nitrification. Observe the differences regarding growth rates, appearance, carbon source, etc. c. Nuisance organisms, e.g. filamentous types and anaerobic degradation of any solids accumulation
TRANS AD-8 Alkalinity-pH Change TRANS AD-9 Effect of pH on Nitrification	2. Discuss pH effects and alkalinity destruction in nitrification.
TRANS AD-10, AD-11 Effect of Temperature I & II	3. Discuss the effect of temperature and the use of correction factors for nitrification.
Note: See USEPA Nitrogen Removal Manual and the Antonie Great Plains article.	4. Discuss the relationship of BOD_5, ammonia concentration and hydraulic loading on nitrification.
TRANS AD-12 Effect of BOD_5 and Hydraulic Load	
TRANS AD-13 Stages-Nitrification	5. Discuss the relationship of inlet ammonia concentration and number of stages on nitrification.
TRANS AD-14 Kinetics of Nitrification	6. Discuss organism growth rates and ammonia oxidation rates a. Nitrite does not accumulate b. Note the factors involved in ammonia oxidation
	7. Discuss other factors e.g., DO requirements and potential denitrification under anaerobic conditions.
	8. Discuss other biological forms e.g., protozoa, rotifers, worm larvae

Module No:	Module Title:
II40WW	Advanced Rotating Biological Surface Operation
	Submodule Title:
Approx. Time: 3.0 Hours	Topic: Process Design and Predicted Performance

Objectives: Upon completion of this topic, the participant will be able to

1. Discuss the primary factors controling the design of RBS units, e.g. hydraulic loading, COD or BOD concentration, NH_3 concentration, staging, rotational speed, temperature.
2. Discuss typical predicted performance including BOD reduction, nitrification, sludge settleability and production.

Instructional Aids:

Slides and Transparencies: Process design curves
Process performance curves

Instructional Approach:

Discussion

References:

1. Water Pollution Control Federation, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, 1976
2. Autotrol Corporation, Bio-surf Design Manual, 1972
3. Autotrol Corporation, Operating & Maintenance Manual for the Bio-surf Waste Treatment Process
4. Articles from the technical literature

Class Assignments:

Study references readings.
Study handout materials.

ERIC

Module No: II40WW	Topic: Process Design and Predicted Performance

Instructor Notes:	Instructor Outline:
TRANS. AD-15, AD-16 Bio-surf Process Design I, II	1. Discuss the factors affecting design a. Hydraulic loading and inlet BOD b. Temperature corrections for BOD removal c. Ammonia reduction factors e.g., inlet BOD, NH_3N and hydraulic loading d. Flow variations re-nitrification e. Temperature corrections for nitrification 2. Discuss typical predicted performance a. BOD reduction b. Nitrification c. Suspended solids levels d. Bio-solids settlability and sludge thickness

Module No:	Module Title: Advanced Rotating Biological Surface Operation
II40WW	Submodule Title:
Approx. Time: 5.0 Hours	Topic: Factors Affecting Process Performance with Operational Changes.

Objectives: Upon completion of this topic, the participant will be able to

1. Describe and discuss the impact of changing wastewater quality, e.g., increase in solids, toxics, pH, loadings, temperature, industrial wastes on RBS unit performance and recommend potential solutions to these changes.
2. Discuss the impact of diurnal flow changes and other flow rate changes and recommend operational changes.

Instructional Aids:

Slides and Transparencies: Affect of wastewater quality change on performance --graphs of effects.
Equalization recommendations.

Instructional Approach:

Discussion

References:

1. Water Pollution Control Federation, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, 1976
2. Autotrol Corporation, Bio-surf Design Manual, 1972
3. Autotrol Corporation, Operating & Maintenance Manual for the Bio-surf Waste Treatment Process
4. Articles from the technical literature

Class Assignments:

Study reference readings.
Study handout materials.

Module No: II40WW	Topic: Factors Affecting Process Performance with Operational Changes
Instructor Notes:	**Instructor Outline:**
Note: Utilize MOP Noll Cause Prevention and Cure Section and Autotrol examples.	1. Discuss the impact of wastewater quality on plant performance and note potential preventive measures a. Increase in solids to units- flow blockage, odors due to anaerobic action b. Toxics may cause loss of bio-mass or decreased activity e.g., heavy metals, cyanides, other-- c. Sharp drops on rises in pH can especially alter nitrification rates. Note alkalinity availability and water chemistry changes d. Increased organic loadings could result in decreased performance and also affect the extent of nitrification e. Significant drops in temperature may decrease performance.
TRANS AD-15, AD-16 Bio-surf Process Design Note:	2. Discuss the impact of diurnal flows and surge flows on the bio-mass and final clarifier performance. Note critical aspect of a. Hydraulic loading on RBS units b. Overflow rate on final clarifier

Module No: II40WW	Module Title: Advanced Rotating Biological Surface Operation
	Submodule Title:
Approx. Time: 2.5 Hours	Topic: RBS Plant Modifications

Objectives: Upon completion of this topic, the participant will be able to

1. Describe potential RBS unit modifications on concepts including air drive, staging, recycle.
2. Describe the potential use of chemical addition to improve pre-treatment on final clarification.
3. Describe alternate pre-treatment modifications to affect RBS unit performance.

Instructional Aids:

Slides or Transparencies: Air drive system
Typical chemical additions

Instructional Approach:

Discussion

References:

1. Water Pollution Control Federation, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, 1976
2. Autotrol Corporation, Bio-surf Design Manual, 1972
3. Autotrol Corporation, Operating & Maintenance Manual for the Bio-surf Waste Treatment Process
4. Articles from the technical literature

Class Assignments:

Study class handout material.

Module No: II40WW	Topic: RBS Plant Modifications

Instructor Notes:	Instructor Outline:
TRANS AD-17 Bio-surf Air Drive	1. Discuss the effect of staging on performance. 2. Consider the aspects of recycle similar to a trickling filter system. Costs and benefits. 3. Discuss the air-drive concept for power reduction, rotational speed adjustment and an additional oxygen source. Aero-tubes can be included for high organic loading applications. 4. Discuss the use of coagulants and coagulant aids to improve solid-liquid separation in primary units and/or final clarifiers. a. Benefits vs. costs b. Sludge aspects 5. Review alternative pre-treatment processes that could be employed to affect RBS performance. a. Grit removal-use of aerated grit chambers. b. Use of fine screens. c. Dissolved air flotation-grease and oil. d. Other 6. Ask participants to cite any of their experiences.

Module No: II40WW	Module Title: Advanced Rotating Biological Surface Operation
	Submodule Title:
Approx. Time: 2.5 Hours	Topic: RBS System: Case Studies

Objectives: Upon completion of this topic, the participant will be able to

1. Discuss the application of the RBS system as the primary secondary treatment unit and as a nitrifying unit in municipal wastewater treatment systems of varying size and type.

Instructional Aids:

Slides and Transparencies: Case studies including Gladstone Michigan
Emmetsburg, Iowa
Spencer, Iowa
others
e.g. Peoria, Illinois

Instructional Approach:

Discussion

References:

1. Water Pollution Control Federation, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, 1976
2. Autotrol Corporation, Bio-surf Design Manual, 1972
3. Autotrol Corporation, Operating & Maintenance Manual for the Bio-surf Waste Treatment Process
4. Articles from the technical literature

Class Assignments:

Study handout materials regarding the case studies.

Module No: II40WW	Topic: RBS System: Case Studies

Instructor Notes:	Instructor Outline:
TRANS AD-18 Gladstone-Flow Diagram TRANS AD-19 Gladstone-Design Data TRANS AD-20 Gladstone-RBS Configuration TRANS AD-21 Gladstone-Performance See Malhotra and Antonie articles regarding Gladstone SLIDES DS-2 through DS-17 TRANS AD-22 Plant Upgrading-Newell	1. Discuss case studies of the use of the RBS system a. Gladstone, Michigan-designed for BOD reduction but achieved nitrification-excellent set of data and analysis of performance. Note performance data. b. Emmetsburg, Iowa-BOD and Ammonia removal plus disinfection (Obtain current information from IDEQ Staff and Mr. Harris of Emmetsburg.) c. Newell, West Virginia d. Discuss additional projects familiar to the instructor e. Have students share their experiences

Module No: II40WW	Module Title: Advanced Rotating Biological Surface Operation
	Submodule Title:
Approx. Time: 1.5 Hours	Topic: RBS System: Special Applications

Objectives: Upon completion of this topic, the participant will be able to

1. Discuss applications of the RBS system to the treatment of side stream flows in wastewater treatment plants including digester supernatant, sludge filtrates, septic effluents.
2. Discuss applications of the RBS system to the treatment of industrial wastes, e.g. dairy, cheese, oil, food processing.

Instructional Aids:

Transparencies and Slides: Typical treatment systems--case studies.
Results of reported studies, e.g. Chi. San. District, Minn-St. Paul San. District, Fredericksburg and Hopkinton, Iowa

Instructional Approach:

Discussion

References:

1. Water Pollution Control Federation, Operation of Wastewater Treatment Plants, Manual of Practice No. 11, 1976
2. Autotrol Corporation, Bio-surf Design Manual, 1972
3. Autotrol Corporation, Operating & Maintenance Manual for the Bio-surf Waste Treatment Process
4. Articles from the technical literature

Class Assignments:

Study handout materials regarding case studies.

Module No: II40WW	Topic: RBS System: Special Applications

Instructor Notes:	Instructor Outline:
TRANS AD-23 Bio-disk (Textile Waste) TRANS AD-24 Bio-module - Septic Tanks Note: Data on Iowa plants from IDEQ and plants themselves. Data on additional industrial applications via WPCF literature and Autotrol in Milwaukee.	1. Discuss special applications in municipal plants a. RBS units have been studied for treatment of sludge treatment flows e.g., digester supernatant, vacuum filtrate, e.g. Chicago Sanitary District, Minn.-St. Paul Sanitary District. b. RBS Units have been suggested to treat septic tank effluents and similar flows e.g., imhoff tanks 2. RBS units have been studied for several industrial waste applications and many plants are in operation a. Dairy wastes at Hopkinton and Fredericksburg, Iowa b. Oil refinery wastes at Salt Lake City for BOD, phenol and oil reduction c. Textiles at DuPont (Chattanooga, Tenn.) BOD reduction and nitrification

TRANSPARENCIES

for

Training Module II40WW

Advanced Rotating Biological Surface

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Module No: II2FWW, II3JWW, II4OWW	Topic: References Utilized in Developing Training Module Material

Instructor Notes:	Instructor Outline:

Water Pollution Control Federation, Operation Wastewater Treatment Plants, MOP No.11, 1976

Autotrol Corporation, Bio-surf Design Manual, 1972

Autotrol Corporation, Operating and Maintenance Manual for the Bio-surf Waste Treatment Process

Autotrol Corp., "Bio-surf Process Package Plants for Secondary Wastewater Treatment", 975-1.1.2, 1975

Autotrol Corp., "The Bio-surf Process", (G-3-876), 1976

U.S.E.P.A., "Process Design Manual for Nitrogen Control", October 1975

Metcalf & Eddy, Inc. Wastewater Engineering, McGraw-Hill, 1972

Clark, J.W., Viessman, W. Jr and Hammer, M., Water Supply and Pollution Control, IEP, 1977

Sawyer, C.N. & McCarty, P.L., Chemistry for Sanitary Engineers, McGraw-Hill 1967

APHA, Standard Methods for the Examination of Water and Wastewater, 14th Edit. 1975

WPCF, Simplified Laboratory Procedures for Wastewater Examination, MOP No. 18, 1970

U.S.E.P.A., Methods for Chemical Analysis of Water and Wastes, 1974

Mather, Stanley E.J. "Plant Upgraded With Rotating Biological Surface System", Public Works, Jan. 1977

Congram, G.E., "Biodisk Improves Effluent-Water-Treating Operation", Oil & Gas Journal, Feb. 1976

Module No: II2FWW, II3JWW, II4OWW	Topic: References Utilized in Developing Training Module Material

Instructor Notes:	Instructor Outline:

Water Pollution Control Federation, Operation Wastewater Treatment Plants, MOP No. 11, 1976

Autotrol Corporation, Bio-surf Design Manual, 1972

Autotrol Corporation, Operating and Maintenance Manual for the Bio-surf Waste Treatment Process

Autotrol Corp., "Bio-surf Process Package Plants for Secondary Wastewater Treatment", 975-1.1.2, 1975

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U.S.E.P.A., "Process Design Manual for Nitrogen Control", October 1975

Metcalf & Eddy, Inc. Wastewater Engineering, McGraw-Hill, 1972

Clark, J.W., Viessman, W. Jr and Hammer, M., Water Supply and Pollution Control, IEP, 1977

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Congram, G.E., "Biodisk Improves Effluent-Water-Treating Operation", Oil & Gas Journal, Feb. 1976

TRANSPARENCIES

for

Training Module II40WW

Advanced Rotating Biological Surface

ROLE of RBS UNITS

SECONDARY TREATMENT

- Reduction of BOD by aerobic biological treatment
- Used in place of a rock trickling filter or an activated sludge process
- Applied to municipal and to industrial wastewater
- Oxidize some organics in industrial wastes

TERTIARY TREATMENT

- Decrease ammonia nitrogen (NH_3-N) concentration by biological oxidation
- Used alone or in combination with other biological processes

TRANS AD-1

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ROTATING BIOLOGICAL SURFACE REACTOR

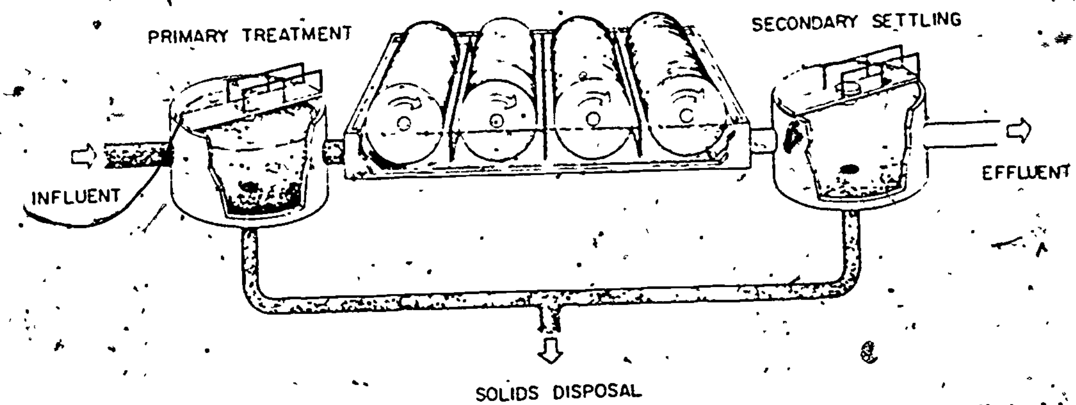


FIGURE 10-5. Rotating biological reactors should be preceded by pretreatment and followed by secondary sedimentation.

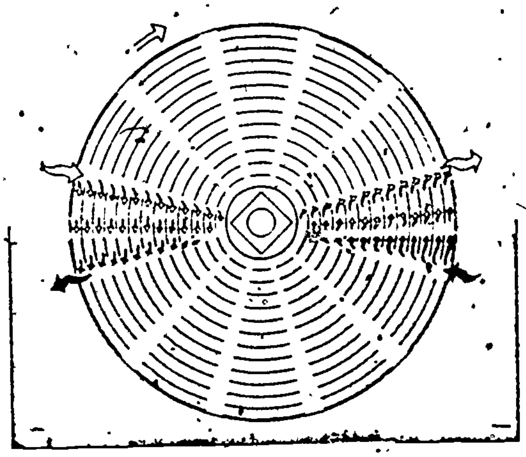
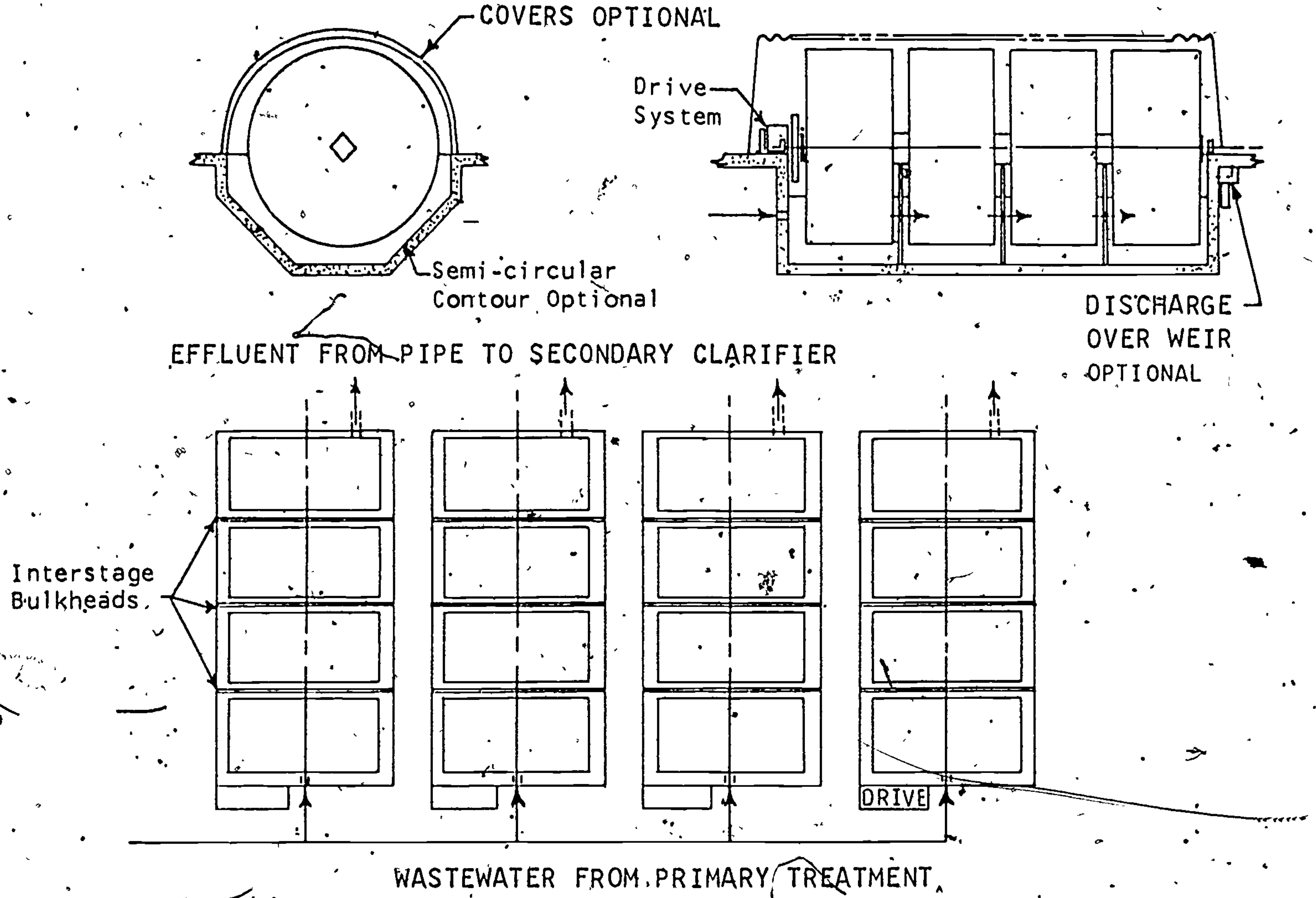


FIGURE 10-4. Reactor carries film of wastewater into the air. Wastewater trickles down the surface and absorbs oxygen from the air.

TRANS AD-2

TRANS AD-3

TYPICAL RBS CONFIGURATION



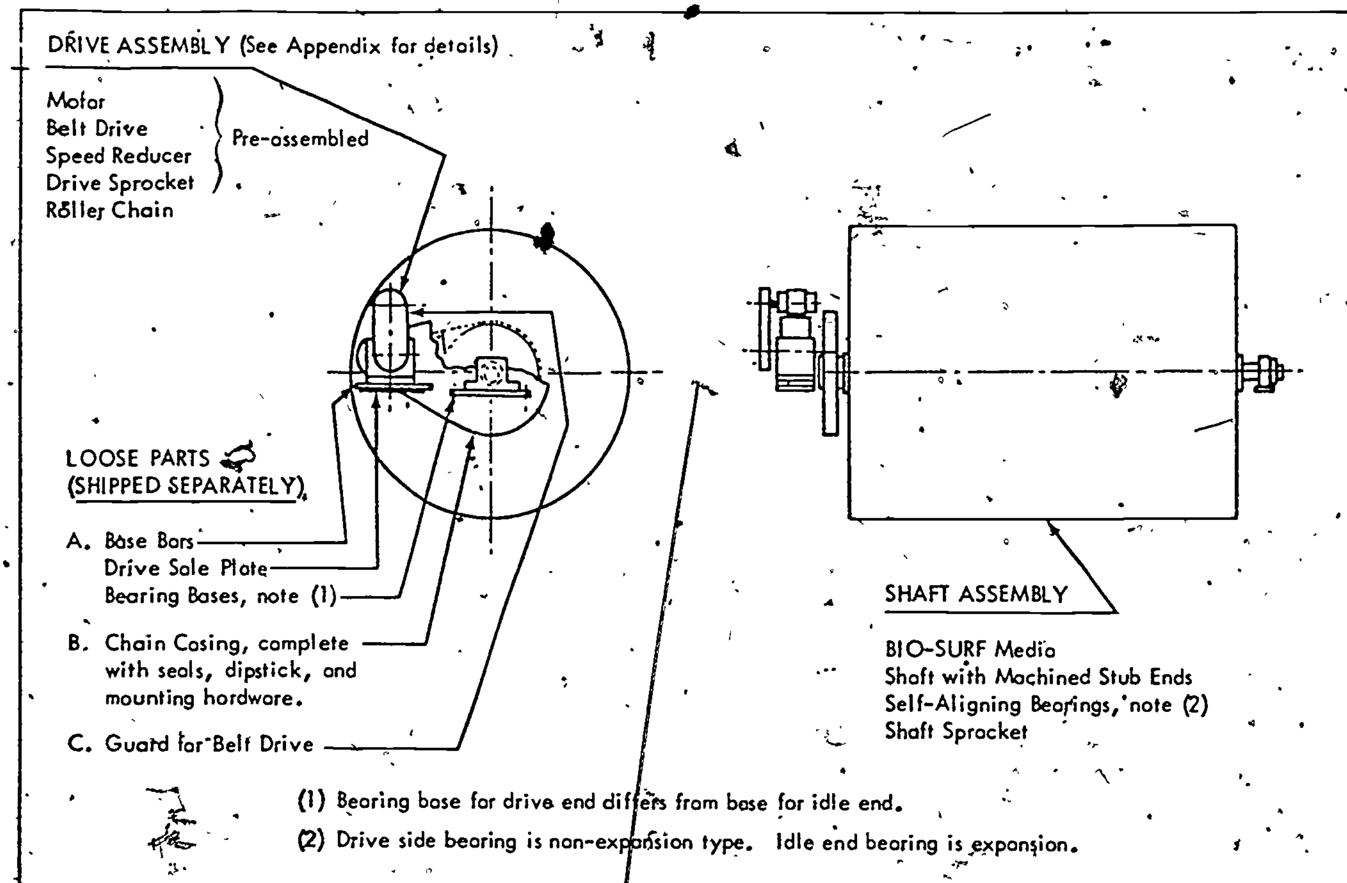
AUTOTROL CORPORATION BIO-SYSTEMS DIVISION

Figure E-1

CONFIGURATION NO. 1
FOUR-STAGE BIO-SURF SHAFTS
IN PARALLEL

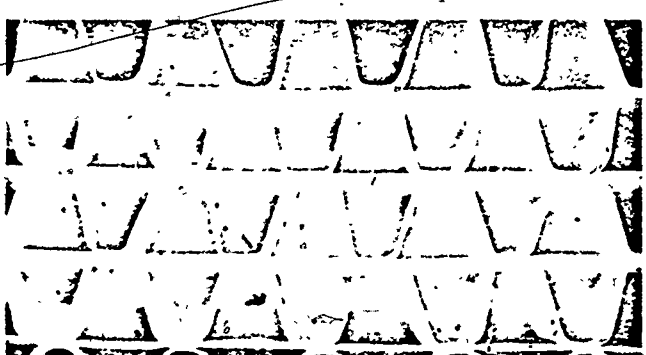
Drg No A-0025

21



BIO-SURF Media

The photo shows a cross-section of the BIO-SURF media. It consists of alternating flat and corrugated sheets of polyethylene which are thermally bonded for strength and long service life. The corrugated sheets are vacuum-formed with integral radial passages. The radial passages allow a free flow of wastewater, air and stripped biomass in and out of the media as it rotates.



PROCESS DESCRIPTION *

The BIO-SURF process is a secondary biological treatment system. It consists of from 2 meter to 12-foot diameter corrugated polyethylene media, which is mounted on a horizontal shaft up to 20 feet long and placed in a steel or concrete tank. The media is rotated at 1.5-3 rpm while about 40% of the surface area is immersed in wastewater.

Shortly after start-up, microorganisms begin to grow on the surface of the media. One to two weeks later, the entire surface area is covered with a 2-4 mm thickness of biomass.

Rotation of the media alternately contacts the biomass with the wastewater for removal of organic materials and exposes it to the air for absorption of oxygen. The amount of attached biomass is relatively large compared to the amount of wastewater under treatment -- the equivalent of 10,000 to 20,000 mg/l of mixed liquor volatile solids. This allows high degrees of treatment to be achieved for relatively short retention times -- usually about one hour for most treatment requirements.

Rotation of the media at a peripheral velocity of 1.0 foot per second exerts shearing forces on the biomass which strips excess biological growth and prevents clogging. The mixing action of the media keeps stripped biological solids in suspension until the flow of treated wastewater carries them to a clarifier for separation and disposal.

<u>Excerpts from Autotrol Publications</u>

Power Requirements	-	0.3 hp-hr per pound BOD removed
Effluent Quality	-	Some applications can achieve effluents of less than 10 mg/l BOD and suspended solids and less than 1.mb/l of ammonia nitrogen
Settling	-	Solids settling rate 10 to 15 ft/hour Low solids loadings. Can achieve 3 to 4% sludge solids
Modules	-	Can be of modular construction to aid expansion

* From Autotrol Corporation publications

BIOLOGICAL TERMINOLOGY

FOOD or SUBSTRATE, F (BOD, COD, TOC) → SYNTHESIS or GROWTH NEW CELLS, M (Volatile Solids)

→ ENERGY & END PRODUCTS*

F/M - Food to Microorganism Ratio

* ORGANIC - HETEROTROPHS

AEROBIC (Presence of D.O.) --- $CO_2 + H_2O$

ANAEROBIC (Absence of D.O.) -- $CH_4 + CO_2$

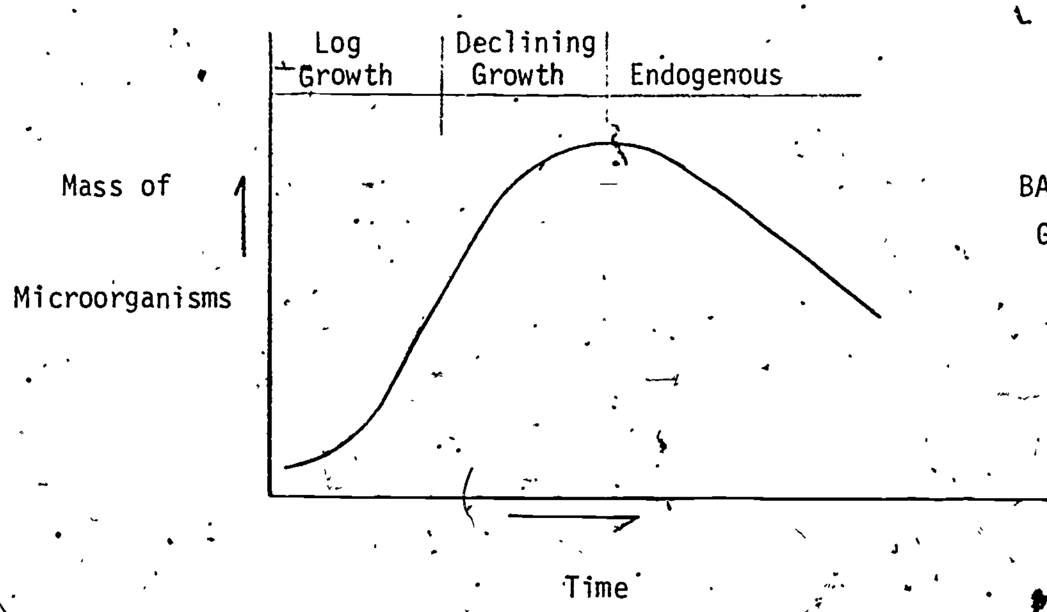
FACULTATIVE -- Can adjust to presence or absence of D.O.

* INORGANIC - AUTOTROPHS

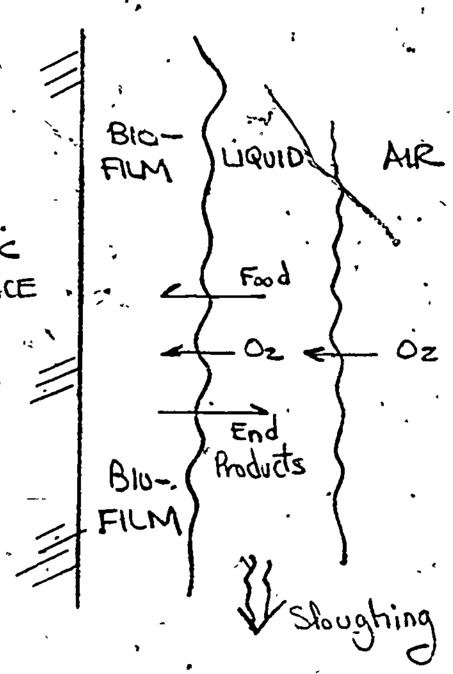
NITRIFICATION -- $NH_3 \rightarrow NO_2 \rightarrow NO_3$

(Aerobic) (Uses CO_2 as carbon source)

PHOTOSYNTHESIS -- Uses CO_2 as carbon source
Yields oxygen in presence of light
e.g. algae



BACTERIAL GROWTH CURVE



FIXED FILM BIO-ACTIVITY (Attached Growth)

TRANS AD-7

ALKALINITY-pH CHANGE IN NITRIFICATION

OVERALL REACTION:

$$NH_4^+ + 2O_2 + 2HCO_3^- \rightarrow NO_3^- + 2H_2CO_3 + H_2O$$

When synthesis is neglected,

- 7.14 mg of alkalinity is destroyed per mg of ammonia nitrogen oxidized - Theoretical

Experimental Data

$$6.3 \text{ to } 7.4 \ \frac{\text{mg alkalinity destroyed}}{\text{mg } NH_4^+ - N \text{ oxidized}}$$

pH CHANGE:

$$pH = pK_1 - \log \frac{[H_2CO_3]}{[HCO_3^-]}$$

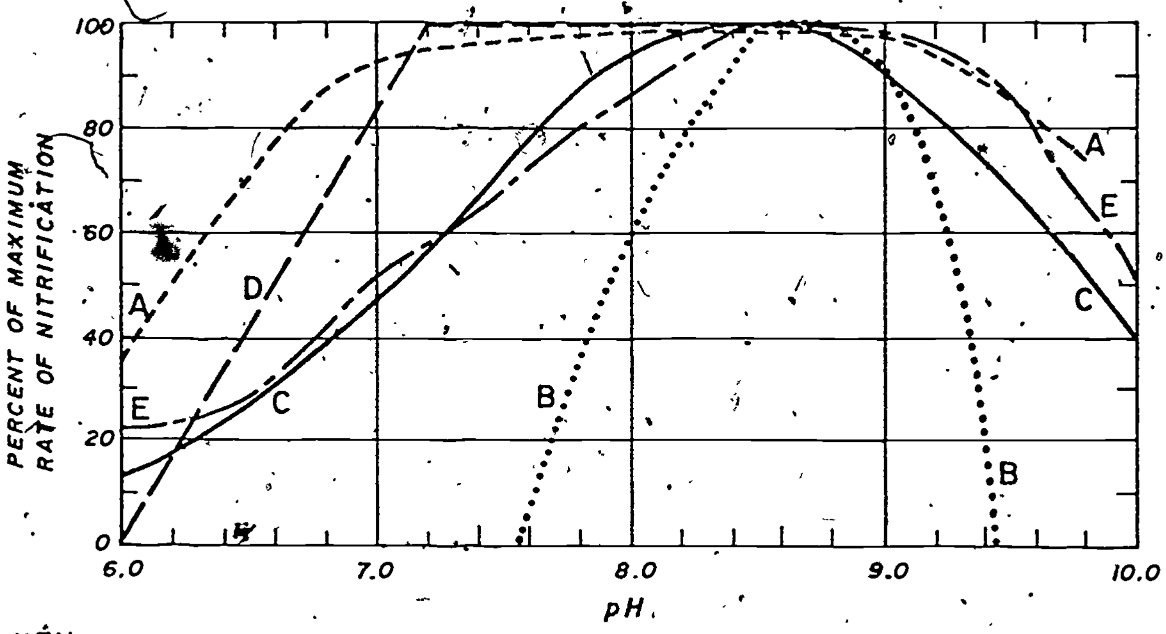
$[HCO_3^-]$ is reduced and $[H_2CO_3]$ is increased

Therefore:

pH tends to be reduced -- is affected by total alkalinity available & CO_2 stripping via aeration & turbulence

FIGURE 3-5

EFFECT OF pH ON NITRIFICATION RATE
(AFTER SAWYER, ET AL.)



KEY

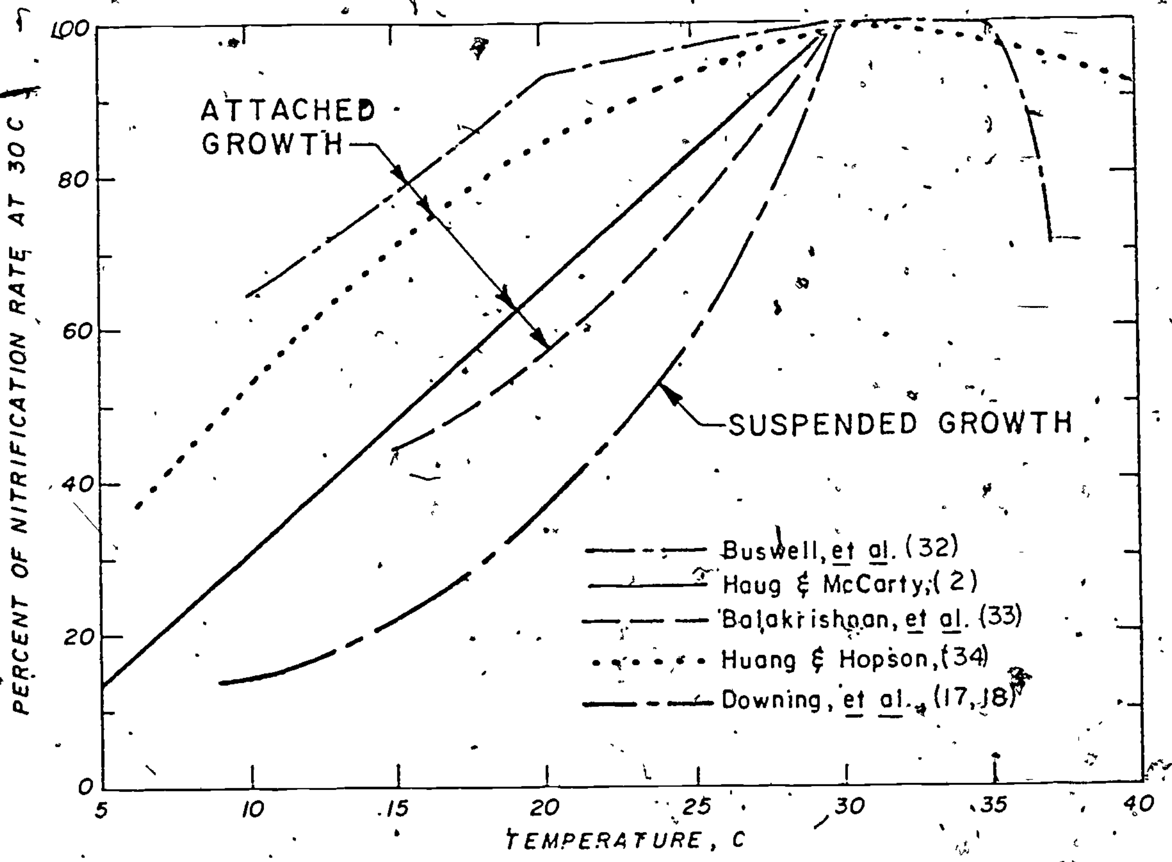
SYMBOL	ENVIRONMENT	REFERENCE
A	Nitrosomonas - pure culture	Engle and Alexander (40)
B	Nitrosomonas - pure culture	Myerhof (41)
C	Activated sludge at 20 C	Sawyer, et al. (42)
D	Activated sludge	Downing, et al. (43)
E	Attached growth reactor at 22 C	Huang and Hopson (34)

the nitrification rate simultaneously. It has been shown that the combined effect of several limiting factors on biological growth can be introduced as a product of Monod-type factors:[46]

$$\mu_N = \hat{\mu}_N \left(\frac{L}{K_L + L}\right) \left(\frac{N}{K_N + N}\right) \left(\frac{P}{K_P + P}\right) \qquad (3\text{-}17)$$

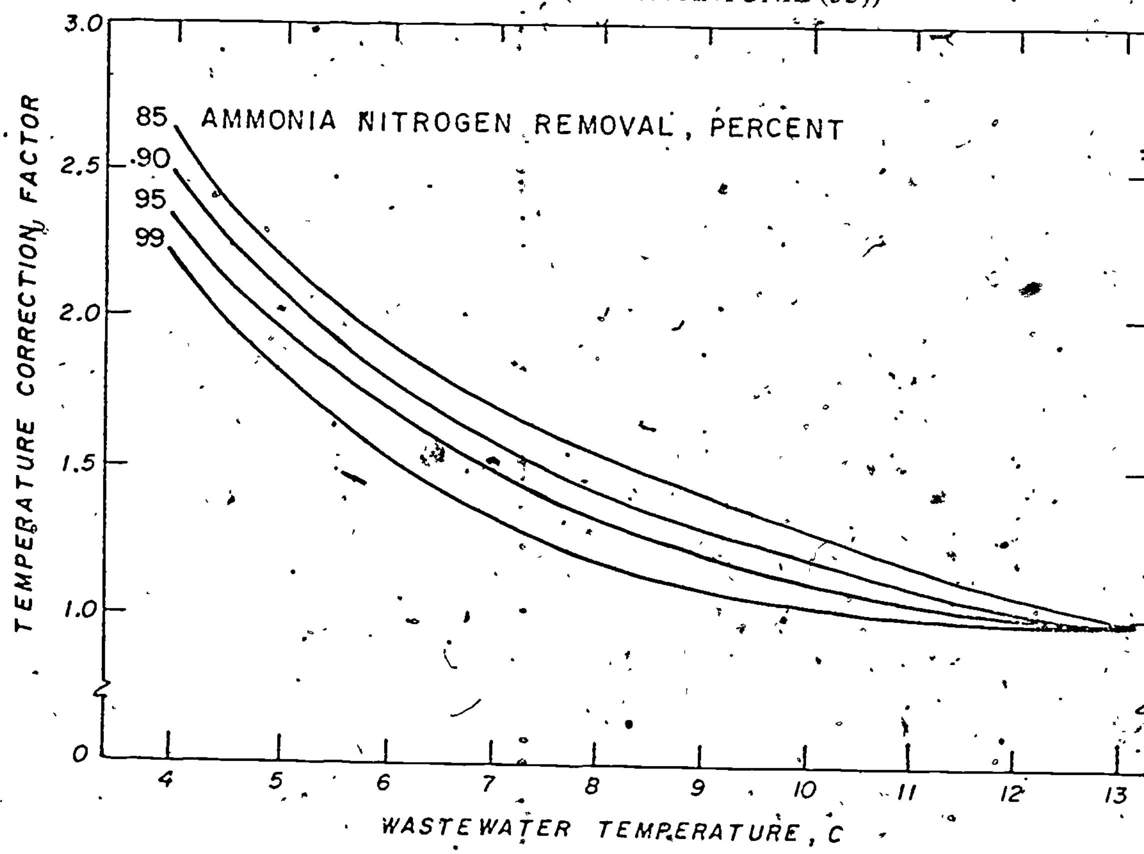
where: L = concentration of growth limiting substance L,
N = concentration of growth limiting substance N,
P = concentration of growth limiting substance P, and
K_L, K_N, and K_P = half-saturation constants for substances L, N, and P, respectively.

COMPARISON OF EFFECT OF TEMPERATURE ON NITRIFICATION IN SUSPENDED GROWTH AND ATTACHED GROWTH SYSTEMS (REFERENCE 34)



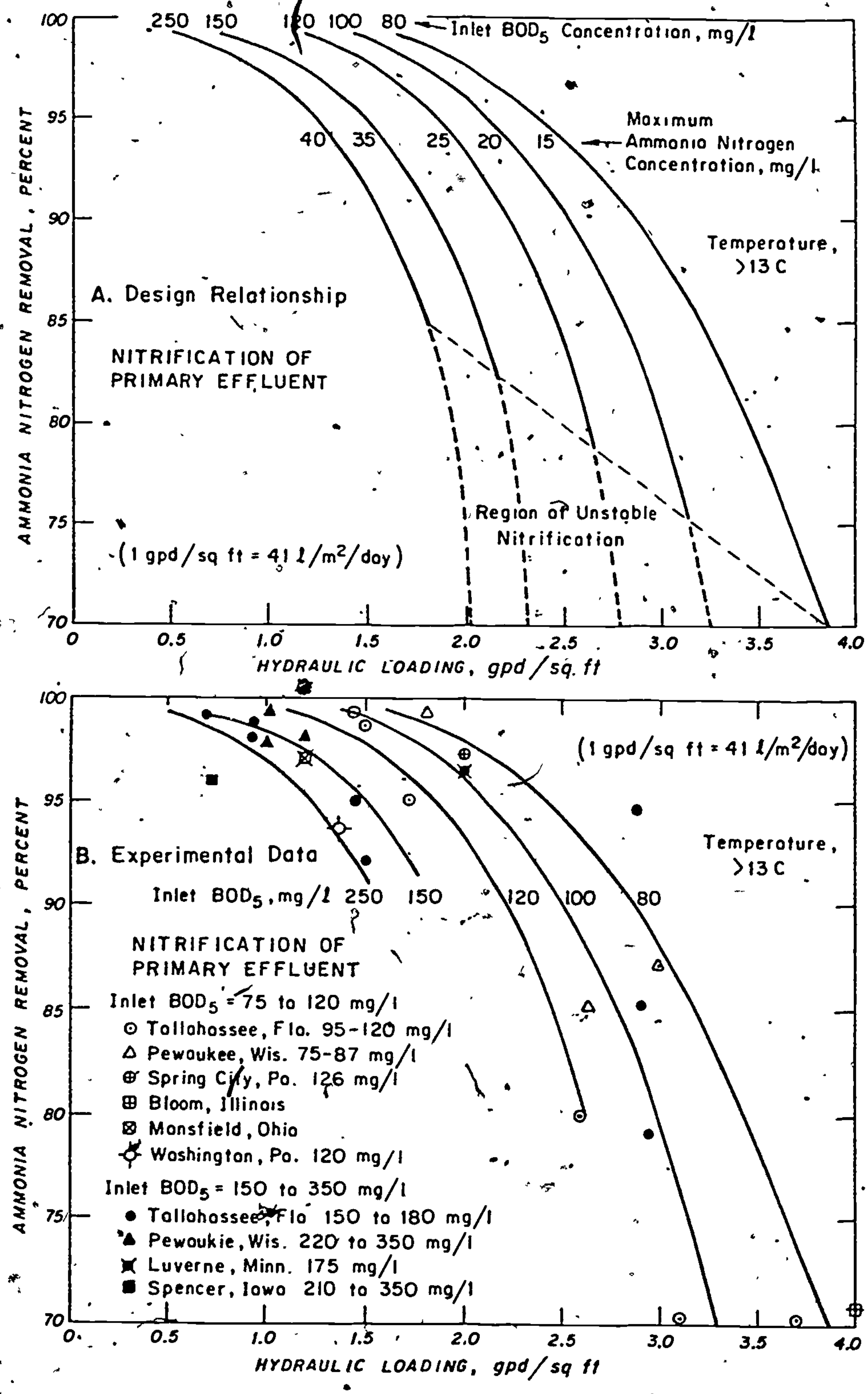
3-11

TEMPERATURE CORRECTION FACTOR FOR NITRIFICATION IN THE RBD PROCESS (AFTER ANTONIE (53))



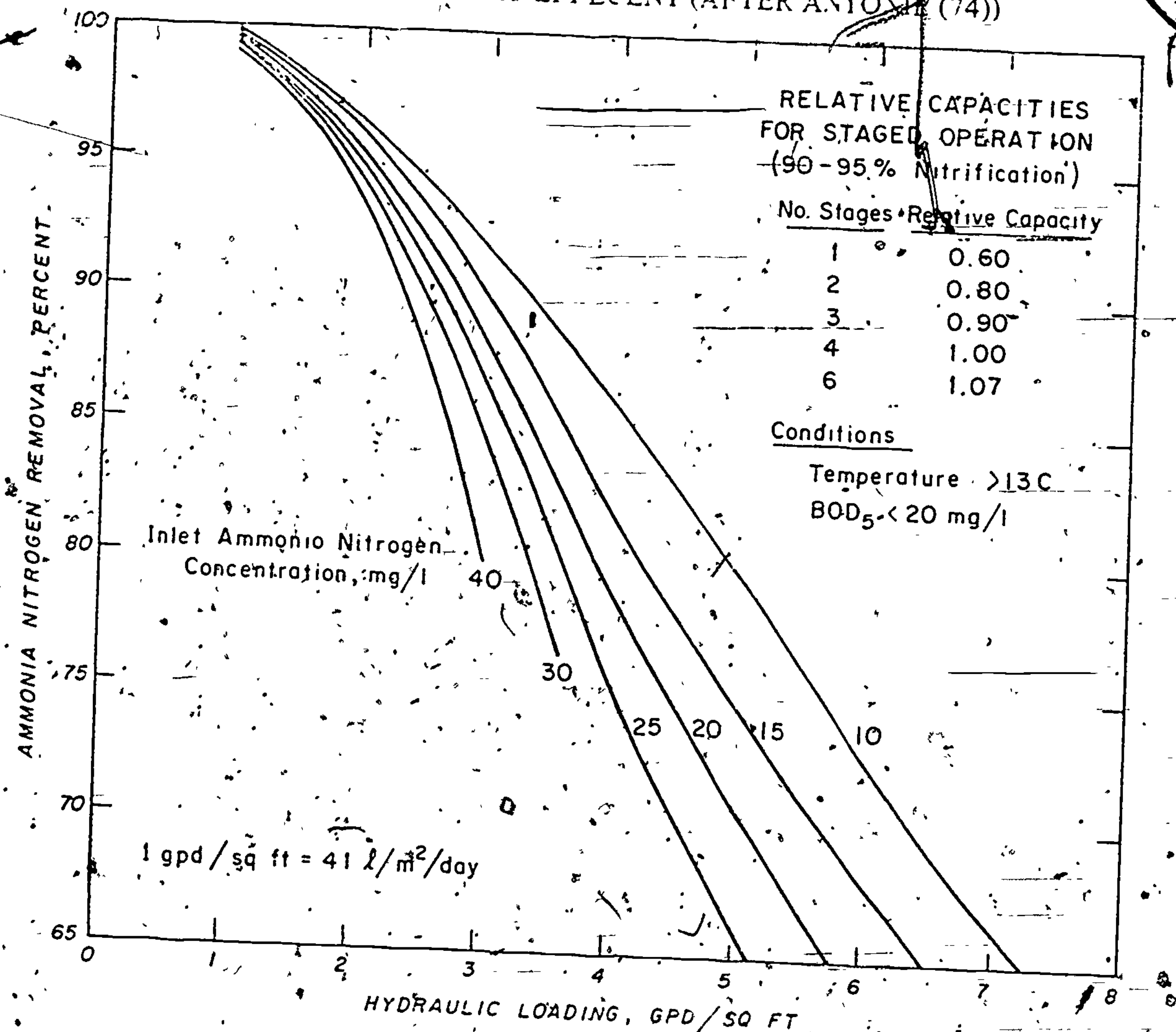
4-45

EFFECT OF BOD_5 CONCENTRATION AND HYDRAULIC LOAD ON NITRIFICATION IN THE RBD PROCESS (AFTER ANTONIE (53))



STAGES-NITRIFICATION

DESIGN RELATIONSHIPS FOR A 4-STAGE RBD PROCESS TREATING SECONDARY EFFLUENT (AFTER ANTONIE (74))



growth kinetics of *Nitrosomonas* and *Nitrobacter*. *Nitrosomonas'* growth is limited by the concentration of ammonia nitrogen, while *Nitrobacter's* growth is limited by the concentration of nitrite.

The kinetic equation proposed by Monod[13] is used to describe the kinetics of biological growth of either *Nitrosomonas* or *Nitrobacter*:

$$\mu = \hat{\mu} \frac{S}{K_s + S} \qquad (3\text{-}10)$$

where:

μ = growth rate of microorganisms, day^{-1},

$\hat{\mu}$ = maximum growth rate of microorganisms, day^{-1},

K_s = half velocity constant = substrate concentration, mg/l, at half the maximum growth rate and

S = growth limiting substrate concentration, mg/l.

Since the maximum growth rate of *Nitrobacter* is considerably larger than the maximum growth rate of *Nitrosomonas*, and since K_S values for both organisms are less than 1 mg/l-N at temperatures below 20 C, nitrite does not accumulate in large amounts in biological treatment systems under steady state conditions. For this reason, the rate of nitrifier growth can be modeled with Equation 3-10 using the rate limiting step, ammonia conversion to nitrite. For cases where nitrite accumulation does occur, other approaches are available.[14,15,16]

3.2.5.2 Relationship of Growth Rate to Oxidation Rate

The ammonia oxidation rate can be related to the *Nitrosomonas* growth rate, as follows:

$$q_N = \frac{\mu_N}{Y_N} = \hat{q}_N \frac{N}{K_N + N} \qquad (3\text{-}11)$$

where:

μ_N = *Nitrosomonas* growth rate, day^{-1},

$\hat{\mu}_N$ = peak *Nitrosomonas* growth rate, day^{-1},

$\hat{q}_N = \frac{\hat{\mu}_N}{Y_N}$ = peak ammonia oxidation rate, lb $NH_4^+ - N$ oxidized/lb VSS/day,

q_N = ammonia oxidation rate, lb $NH_4^+ - N$ oxidized/lb VSS/day

Y_N = organism yield coefficient, lb *Nitrosomonas* grown (VSS) per lb $NH_4^+ - N$ removed,

N = $NH_4^+ - N$ concentration, mg/l, and

K_N = half-saturation constant, mg/l $NH_4^+ - N$, mg/l.

BIO-SURF PROCESS DESIGN PROCEDURES

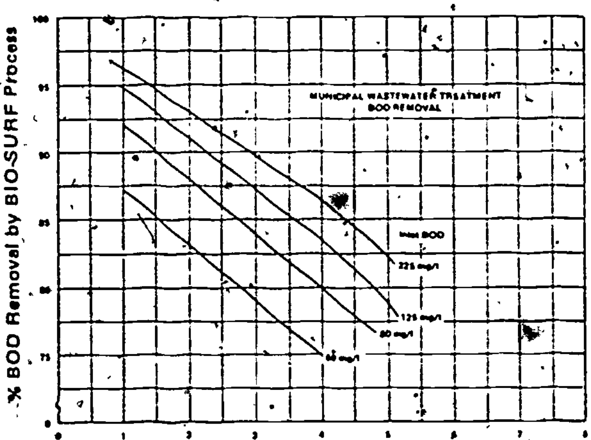
BOD Removal

Hydraulic loading has been found to be the principle design criterion for the BIO-SURF process. To determine the amount of BIO-SURF media required for a specific application requires simply that the appropriate hydraulic loading be selected from the figure below. Dividing the design flow by the hydraulic loading rate yields the amount of BIO-SURF media surface area required.

The BOD removals shown in Figure 1 are for the BIO-SURF process after secondary clarification and do not include any BOD reduction from primary treatment. When using fine screening or septic tanks for pretreatment, we suggest that no BOD reduction be credited to the pretreatment. Because the amount of BOD removal by pretreatment is relatively small, this procedure results in just a slight increase in BIO-SURF media requirements and provides a slightly conservative basis for design.

The BIO-SURF process can be designed to consistently produce effluent BOD of 10 mg/l. Effluents of less than 10 mg/l have been produced by the BIO-SURF process when operated at less than its design flow. This points out a significant benefit for the process in that it produces a higher quality effluent when underloaded, unlike other processes which have difficulty operating efficiently when underloaded.

BIO-SURF process effluents of 10-20 mg/l BOD consist of approximately 1/3 soluble and 2/3 insoluble BOD. Where effluent quality of less than 10 mg/l BOD are consistently required, tertiary filtration is recommended.



1

Suspended Solids Removal

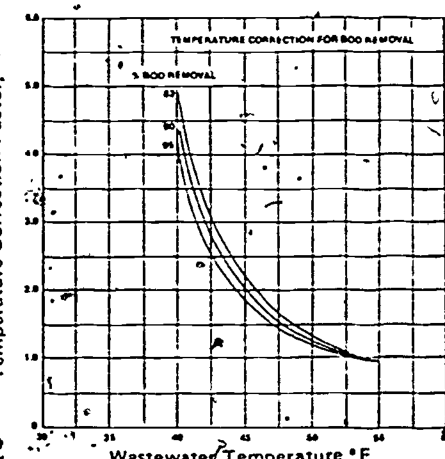
Suspended solids removal occurs in the BIO-SURF process in the same proportion as BOD removal. When the process is designed to achieve a specific effluent BOD concentration, the suspended solids will be at the same or slightly lower concentration.

Septic Tank Effluent

A septic tank provides a very simple means of pretreatment. However, it does produce an effluent which is somewhat more difficult to treat than a fresh waste. Field testing has shown that degrees of treatment equal to those on fresh waste are achieved on septic tank effluent at lower hydraulic loadings. To alter the septic waste to fresh conditions and develop an acclimated culture requires that the amount of BIO-SURF media determined for a fresh waste application be increased by 50% for septic waste.

Temperature Correction

Wastewater temperatures above 55 degrees F do not affect treatment efficiency. Below 55 degrees F, the BIO-SURF process, like all biological treatment systems, will show decreased treatment efficiency. However, by operating at a lower hydraulic loading, equal degrees of treatment can be maintained. Figure 2 shows temperature correction factors which are used to increase the amount of BIO-SURF media for conditions of prolonged low wastewater temperatures.



2

Flow Equalization

The size of the flow equalization tank following pretreatment is determined on the basis of the daily wastewater flow pattern. The purpose of the flow equalization tank is to provide a reasonably uniform wastewater flow to the BIO-SURF process even though most of the daily flow may enter the plant over a relatively short time period. The following are general guidelines for determining the flow equalization tank capacity:

Daily Period when Wastewater Flow is Less than 25% of Average Flow	Recommended Flow Equalization Tank Capacity as Percent of Daily Flow
Hours	%
0	0
4	10
6	15
8	25
12	33
14	50
16	60.
18 or more	67

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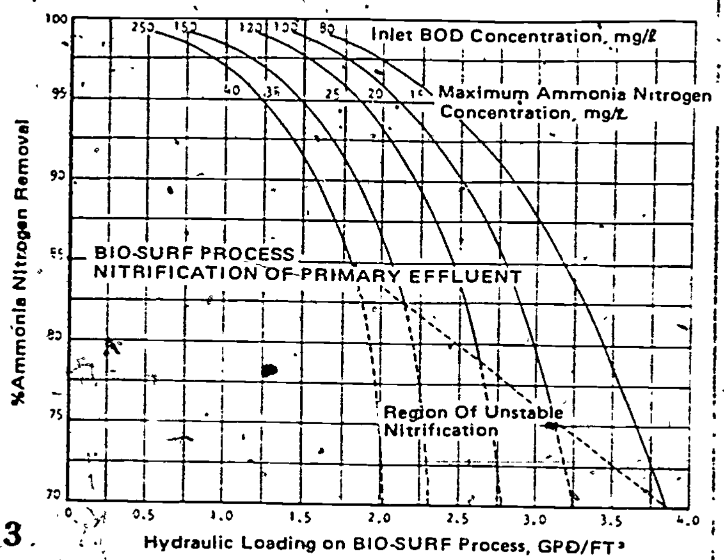
Ammonia Nitrogen Removal

Regulatory agencies are beginning to impose requirements for the removal of nitrogenous oxygen demand, NOD, (as ammonia nitrogen) in addition to BOD and suspended solids removal.

The BIO-SURF process is well-suited to the removal of NOD, because of the natural development of nitrifying organisms in the latter stages of multi-stage BIO-SURF installations.

Figure 3 shows the design relationship for ammonia nitrogen removal. BIO-SURF media requirements for nitrification must be compared to those for BOD removal, and the larger of the two determines equipment selection.



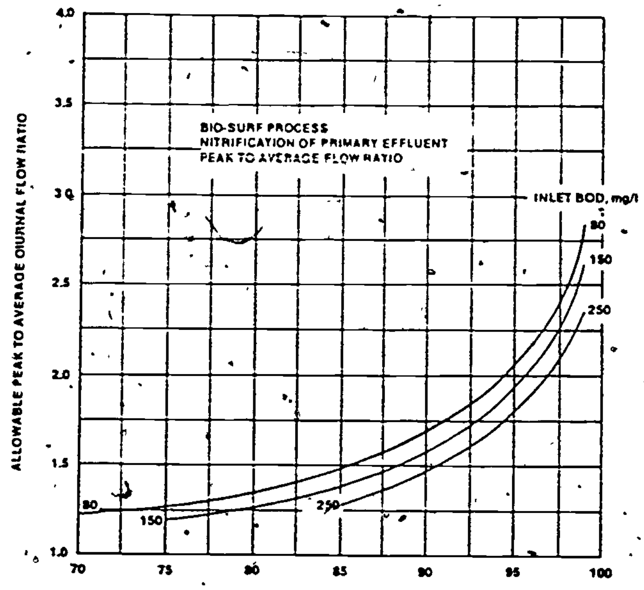
3.

Septic Tank Effluent

As for BOD removal, the lower treatability of septic wastes requires 50% more BIO-SURF media for nitrification.

Peak Flow Correction

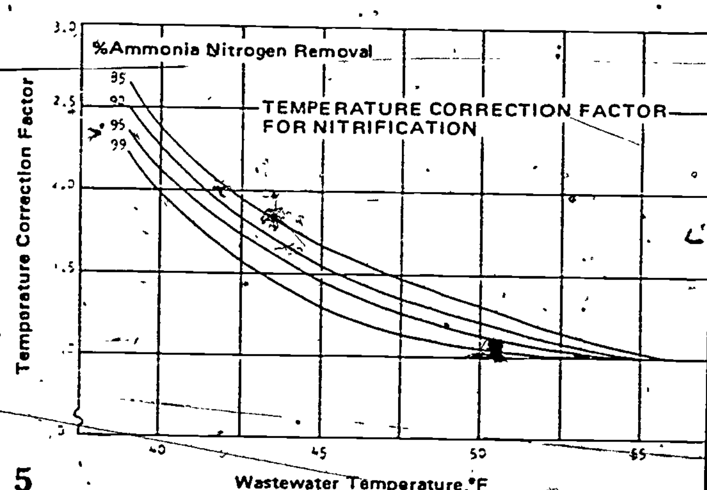
With widely varying flow conditions, there is the danger that nitrifying bacteria may be displaced from the latter stages by the more rapidly growing carbon-oxidizing bacteria. To avoid this, it is necessary to prevent high concentrations of BOD from entering the latter stages. Figure 4 indicates the allowable peak to average flow conditions which will achieve this. If the actual peak to average flow ratio exceeds the allowable value, either flow equalization must be included or the average design flow must be increased along with the required BIO-SURF media area.



4

Temperature Correction

Nitrification efficiency is also decreased by low wastewater temperature. Figure 5 contains temperature correction factors which will compensate for the low temperature conditions.



5

Equipment Selection

When the appropriate amount of BIO-SURF media surface area has been determined from the preceding design procedures, the desired form of BIO-SURF process equipment can be selected from the following pages.

BIO-SURF™ Air Drive System

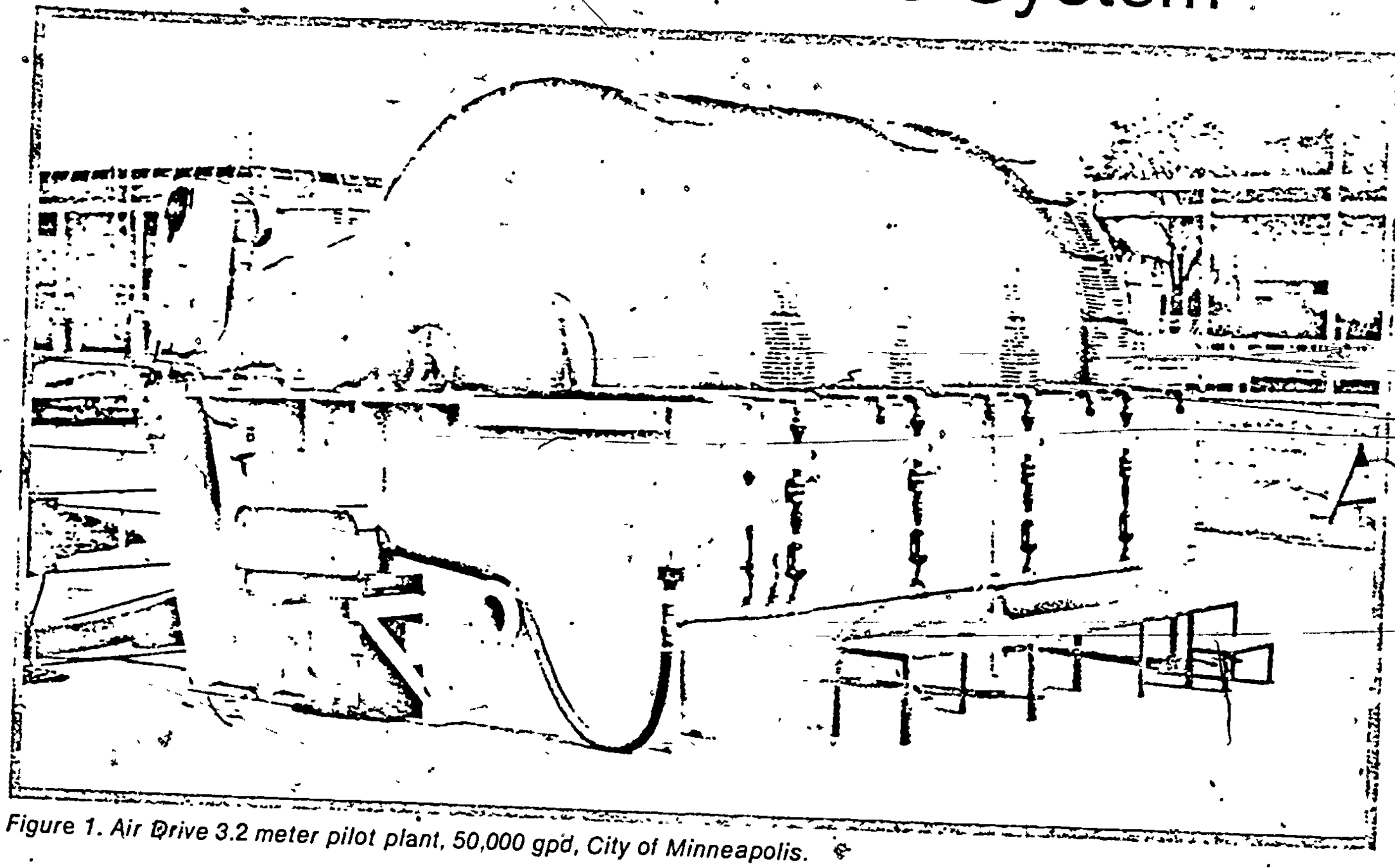


Figure 1. Air Drive 3.2 meter pilot plant, 50,000 gpd, City of Minneapolis.

Continued testing of the proven BIO-SURF process has resulted in new developments which significantly affect capital and operating costs.

One such new development is an alternative drive system for BIO-SURF shaft assemblies:

BIO-SURF AIR DRIVE SYSTEM

The air drive is shown schematically in Figure 2. It consists of attaching plastic cups around the outer perimeter of the media. The shaft of the media is installed in the tank in the normal manner. A small air header is placed below the media and releases air at a low pressure into the attached cups. The captured air exerts buoyant force, which in turn exerts a torque on the shaft sufficient for rotation. Air cups are not placed over those portions of the media containing a radial passage opening. Thus, approximately 20 percent of the released air escapes into the radial passages and flows upward into the corrugated sections.

The supplementary aeration achieved from the cup arrangement is sufficient to allow a reduction in rotational velocity of the media while still achieving the same degree of treatment. This offers the potential for reduction in power consumption for a given application and makes the inherent energy-saving characteristics of the BIO-SURF process even more dramatic.

Figure 3 (over leaf) is a drawing of a full-scale BIO-SURF plant with an air drive system. A blower delivers air at 3-4 psi through a common header. An air volume of 125-250 cfm is withdrawn through a control valve for each shaft and distributed through the header beneath the rotating media.

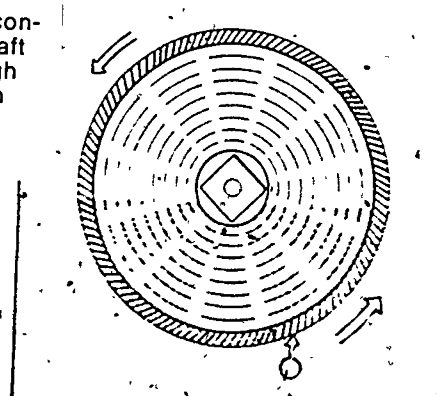


Figure 2. Air Drive schematic.

The simplicity of this drive system is attractive for larger treatment plants employing a large number of BIO-SURF shafts. Rather than having many individual mechanical drive systems, there are now only one or two central blowers delivering air through common headers to drive a large number of shafts. This significantly reduces overall maintenance requirements and allows individual adjustment of rotational speed for each shaft.

Individual speed adjustment enables the operator to optimize power consumption by reducing rotational speed in latter stages of treatment where aeration requirements are reduced. For plants operating at less than design flow, rotational speed can be further reduced to minimize power consumption.

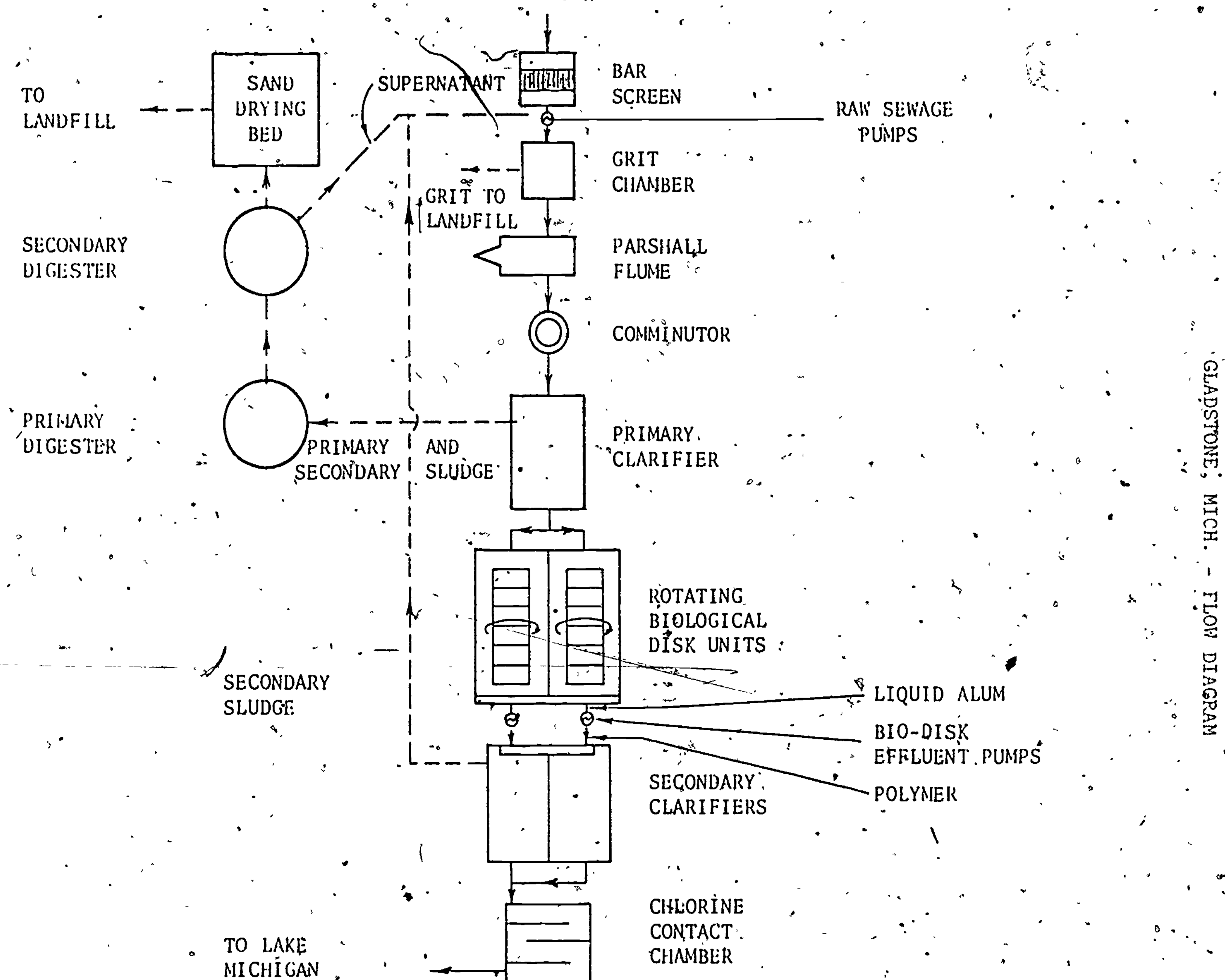


FIGURE I - SCHEMATIC FLOW DIAGRAM

GLADSTONE, MICH. - DESIGN DATA

Design Year	2000
Population Equivalent	10,000
BOD_5	1,670 lbs/day (758 kg/day)
SS	2,000 lbs/day (908 kg/day)
Average Daily Flow	1.0 mgd (3,785 cu m/day)
Peak Flow	2.88 mgd (10,900 cu m/day)

Raw Sewage Pumps	3 @ 1,400 gpm (88.3 l/sec), 2 variable speed, and 1 constant speed (lag pump)
Primary Clarifier	One rectangular 70,000 gallon (265 cu m) capacity with 1.5 hour detention and 895 gpd/sq. ft. (36.5 cu m/day/sq. m) overflow rate.
Bio-disk Units	Two parallel paths with three shafts and six stages in each, 90 minutes retention and 1.94 gpd/sq. ft. (0.097 cu m/day/sq.m) hydraulic loading rate
Bio-disk Effluent Pumps	Same as raw sewage pumps
Secondary Clarifiers	Two rectangular, 2.75 hour detention and 620 gpd/sq. ft. (25.3 cu m/day/sq. m) overflow rate
Chlorine Contact	Two baffled tanks with total retention of 35 minutes
Primary Digester	One fixed cover, 100,000 gallon (378.5 cu. m) capacity with 15.5 days detention at design loading, heated and mixed by gas recirculation.
Secondary Digester	One, floating cover, 100,000 gallon (378.5 cu. m) capacity with supernatant discharge to raw wastewater wetwell
Tank Truck	One, 2,500 gallon (9.4 cu. m) capacity
Drying Beds	Adjoining sanitary landfill site, 600' x 200' (183 m x 61 m) without underdrains
Liquid Alum Storage	Two tanks; each 2,600 gallon (9.8 cu. m) capacity

Bar screen, grit chambers, comminutor, alum and polymer feeders, sludge pumps, chlorine feeding equipment, are all designed for a peak daily flow of 2.88 mgd (10,900 cu. m/day).

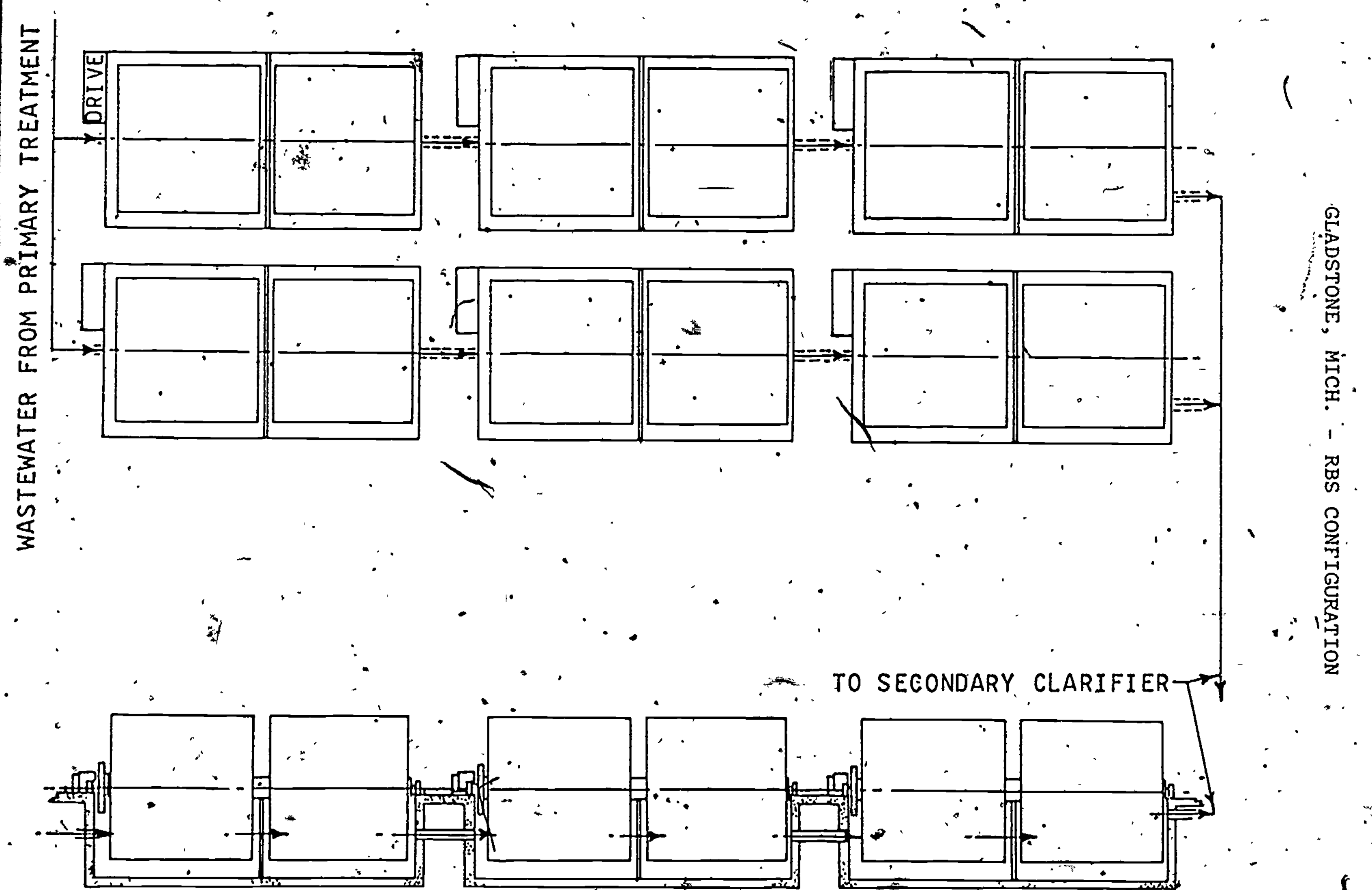


FIGURE 3
Flow Diagram for BIO-SURF Installation

SUMMARY AND CONCLUSIONS

1. Pilot studies for municipal wastewater treatment using the bio-disk process indicated that operation without primary treatment would necessitate at least fine screening of wastewater to avoid accumulation of strings and debris on spacers and shafts. Operation with primary effluent indicated that the process was very stable and effective for providing overall BOD_5 removals of 80 to 92.6% and that, at same hydraulic loading, the BOD removal dropped by about 1% for each 1°C (1.8°F) drop in temperature of the wastewater.

2. The results of these studies were used to design 1.0 mgd (3,875 cu. m/day) facility to provide secondary treatment with phosphorus removal for the City of Gladstone, Michigan which has been in operation since March 1, 1974.

3. During the last 12-months of operation with about 70 mg/l of alum and 0.8 mg/l of liquid anionic polymer (Nalcolyte 677) added after the bio-disk units, the effluent BOD is generally less than 10 mg/l, suspended solids about 15 mg/l and total phosphorus less than 1.6 mg/l.

4. The plant was not designed for nitrification; however, because of lower hydraulic loading, ammonia nitrogen was generally about 1.0 mg/l during summer months and less than 8.5 mg/l during winter months.

5. The high degree of treatment and nitrification achieved resulted in reduction in chlorine dose from a level of 6 to 7 mg/l to a level of 2 to 3 mg/l.

6. Recyclying of secondary sludge to the primary clarifier resulted in a substantial reduction in the total volume of sludge pumped daily to the anaerobic digester.

Plant Upgraded with Rotating Biological Surface System

STANLEY E. J. MATHER
Senior Engineer,
NUS Corporation

THREE YEARS ago the U.S. Environmental Protection Agency (EPA) and the State of West Virginia requested the Newell Company, which owns and operates the existing primary sewage treatment plant for the city of Newell, West Virginia, to upgrade its plant to a secondary treatment system to meet the 95 percent BOD reduction, suspended solids and phosphorus removal.

Newell is an unincorporated town and is therefore not under a municipal authority. Hence the existing plant was designed by R. S. Barckhoff Associates, Salem, Ohio, in 1955 and built by the Newell Company in 1958 to serve the city of Newell as a primary treatment system. In fact, the Newell Company owns and runs both the water supply and sewage treatment systems for the citizens of Newell.

Newell has a population of 2,300, with an average sewage flow of 180,000 gpd. The original design flow for the existing primary treatment plant was 250,000 gpd. The present average BOD of incoming wastewater is 450 mg/L and the average suspended solids is 600 mg/L. The flow is completely domestic, without industrial wastes.

Newell Company engaged the Cyrus Wm. Rice Division of the NUS Corporation to study the problem and provide a sewage treatment plant that would meet EPA requirements, while at the same time have low annual operation and maintenance costs. After different methods of upgrading the plant were considered, the Bio-Surf process, manufactured by Autotrol Corporation, was selected on the basis of economics.

Application was made to the Department of Natural Resources, State of West Virginia, for a permit to construct a facility with a design flow of 400,000 gpd. The design was approved and the plant, which is due on stream in June, 1977, is currently under construction.

The existing primary plant contains a comminutor with a by-pass bar screen, a Parshall flume flow recorder, grit chamber, and primary clarifiers followed by a chlorinator. The sludge is digested anaerobically and air-dried on sand beds. The proposed addition converts the plant to secondary treatment. The Bio-Surf unit is followed by final clarification and disinfection.

The Bio-Surf section is the main component of the process and is made up of a series of 12-foot diameter high density polyethylene sheets vacuum-formed into corrugated sections in order to provide the maximum surface area for microbial growth. The total surface area installed on the 25-foot long shaft is 88,000 square feet. There are two of these shafts making a total surface area of 176,000 square feet. Each is divided into four stages with the flow through the tank being parallel to the shaft and perpendicular to the media. The effluent from the primary clarifiers flows to the multi-stage Bio-Surf section where fixed aerobic cultures of microorganisms remove both dissolved and suspended organic matter from the wastewater.

Part of the organic matter is oxidized to carbon dioxide and water, part is synthesized into additional bio-mass, and part is stored in the bio-mass for oxidation and synthesis at a later time. Simultaneously, as additional bio-mass is generated, excess bio-mass is stripped from the rotating media by the shearing forces exerted by the wastewater.

Each stage of media operates as a completely mixed, fixed-film biological reactor in which there is a dynamic equilibrium between the rate of biological growth and the rate of sloughing of bio-mass. Treated wastewater and sloughed bio-mass pass over weirs to each subsequent stage of media. As wastewater passes from stage to stage it undergoes a progressively increasing degree of treatment by specific biological cultures which are adpated to the changing wastewater. Bio-Surf section effluent is not recirculated and the power requirements to operate the units are negligible.

Excess bio-mass and treated wastewater leaving the last stage of the media pass to two Spiraflo circular secondary clarifiers, manufactured by Lakeside Equipment Corporation. Here the incoming waste enters at the tank periphery and the clarified effluent is drawn out over weirs at the center. Provision has been made to withdraw sludge and skimmings from these clarifiers that can be returned either to the sludge digester or to the inlet end of the existing primary settling tanks. Final disposal of digested sludge after drying is removed by truck to landfill or dumping.

Clarified effluent flows into a chlorine contact tank. A chlorine residual, as stipulated by the regulatory agencies, is maintained by a Wallace & Tiernan gas chlorinator which will be adequate to serve the upgraded secondary plant. Final effluent is then discharged directly into the Ohio River.

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PAGE 41 "BIO DISC SYSTEM SHRINKS BOD 90%"
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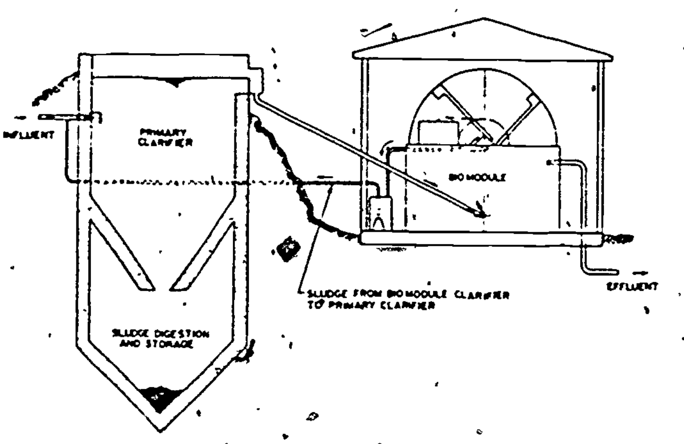
BIO-MODULE AND BIO-MODULE SHAFT CONFIGURATIONS

The following are several suggested configurations in which to employ BIO-SURF process equipment for package plant applications. While the configurations of Figures 6, 7, and 8 show BIO-MODULE units in steel tankage, they are also applicable in BIO-MODULE SHAFTS in concrete tankage.

Aerobic Pretreatment

Several aerobic pretreatment alternatives can be utilized to precede BIO-MODULE units and BIO-MODULE SHAFTS. These include primary clarifiers, combined primary clarifier and sludge storage (Imhoff-tank) or any of the recently developed fine-screening devices. The use of combined primary clarification and sludge storage with a BIO-MODULE unit is shown in Figure 6. Secondary sludge from the BIO-MODULE is returned to the pretreatment system for storage and digestion. Because package plant applications often experience extreme fluctuations in flow, it is often recommended that an aerated flow equalization step be utilized after pretreatment before entering the BIO-MODULE unit. This results in a higher treatment capacity and permits a more economical design for the BIO-MODULE units or BIO-MODULE SHAFTS and the subsequent clarification and disinfection steps.



6 BIO-MODULE WITH PRIMARY CLARIFIER AND SLUDGE DIGESTION

Septic Tank Pretreatment

For the range of wastewater flows from 5,000 to 75,000 gpd, primary treatment and sludge handling can be accomplished simply and effectively with a septic tank. A septic tank by itself is a crude means of wastewater treatment. However, in combination with BIO-MODULE units or BIO-MODULE SHAFTS, it provides for a very simple total treatment system.

Two configurations of a treatment system with a BIO-MODULE and septic tank are shown conceptually in Figures 7 and 8. For each of these configurations, the treatment system is constructed in two parts – the septic tank and a flow equalization tank. For low wastewater flows, these two tanks may be contained in a single tank. For higher flows, they can be separate tanks. The septic tank portion of the pretreatment system provides for removal of settleable and floatable materials. It also provides for digestion and storage of secondary sludge solids.

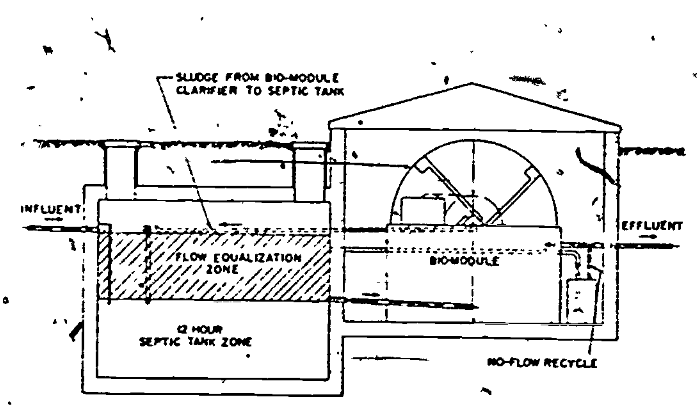
The flow equalization tank in conjunction with the feed chamber and bucket feed system of the BIO-MODULE unit provides a relatively uniform flow of wastewater to the BIO-SURF process regardless of the pattern of raw wastewater flow. Septic tank construction can be of steel or concrete, depending upon cost, soil conditions, and regulatory agency requirements.

Selection of an appropriate septic tank retention time, when followed by BIO-SURF process secondary treatment, is done primarily on the basis of sludge digestion and storage capacity. Field testing has shown that a 12-hour retention time will yield about one year of continuous operation before removal of sludge for ultimate disposal. On this basis, a 12-hour septic tank retention time is recommended for most applications.

During extended periods of little or no wastewater flow, BIO-SURF process effluent can be pumped to the septic tank for recirculation. This will provide sufficient organic matter to maintain an active aerobic biomass on the media until normal wastewater flow is resumed. This practice is recommended in applications such as recreational areas where wastewater treatment is needed only several days each week.

Side-by-Side Configurations

In the side-by-side configuration (Figure 7), gravity wastewater flow to the BIO-MODULE unit is utilized. Raw wastewater enters the septic tank for primary treatment and overflows into the flow equalization tank. The flow equalization tank is connected to the lowest point of the BIO-MODULE feed chamber. At the beginning of a daily flow cycle, the wastewater level in the equalization tank will be at its lowest point. As the flow cycle progresses, the equalization tank will begin to fill: and the rising level in the BIO-MODULE feed chamber will cause the bucket feed mechanism to deliver wastewater at an increasing rate. At the end of the period of flow, wastewater in the equalization tank and feed chamber will be at their highest levels; and the bucket pump will be pumping at its highest rate. During the balance of the daily flow cycle, where there is little or no raw waste flow, the level in the equalization tank will be pumped down by the bucket pumps until the beginning of another flow cycle when it is again at its lowest level. Operating in this manner, the BIO-SURF process experiences a cyclic wastewater flow pattern where the peak flow is approximately 1.5 times the average regardless of the pattern of raw wastewater flow. In cases of extreme surges of wastewater which exceed the capacity of the equalization tank, the excess can overflow from the feed chamber directly into the stages of media and receive full secondary treatment.



7 BIO-MODULE UNIT WITH SEPTIC TANK PRETREATMENT SIDE BY SIDE CONFIGURATION

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STUDENT-PARTICIPANT GUIDE

for

Training Module II40WW

Advanced Rotating Biological Surface

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II40WW ADVANCED ROTATING BIOLOGICAL SURFACE OPERATION

STUDENT OUTLINE

Note: Participants will receive a copy of each transparency used in the presentations. Participants should own or receive WPCF Manual of Practice No. 11, Operation of Wastewater Treatment Plants. Appropriate chapters in the Manual should be studied for each topic.

If possible, technical brochures and articles from manufacturers and/or the literature could also be provided for the student participant.

I. RBS System: Review of Purpose and Components

A. Note the role of RBS systems in treatment (Trans AD-1)

B. Study the process components and the mechanisms by which it functions (Trans AD-2, AD-3, AD-4, AD-5)

II. Basic Biology and Applications to RBS unit

A. Study the types of organisms especially aerobic heterotrophs and autotrophs in an RBS unit (Trans AD-6).

B. Study growth rates, synthesis and affect of food availability and type. (Trans AD-6, AD-7).

C. Study the food-microorganism-oxygen-end products interaction in bio-film process (Trans AD-7).

D. Study the various biochemical interactions in the system.

1. Note pH effects and alkalinity destruction in nitrification (Trans AD-8, AD-9).

2. Note the effect of temperature in nitrification (Trans AD-10, AD-11).

3. Note the effect of BOD_5—NH_3 concentrations and hydraulic loading on nitrification (Trans AD-12).

4. Note the effect of stages on nitrification (Trans AD-13).

5. Note the factors that affect nitrifying bacterial growth and ammonia reduction. Note the rate limiting step. (Trans AD-14).

E. Observe the additional types of biological life present in a system and what they indicate.

1. Filamentous organisms - substrate changes

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2. Protozoa - prey on bacteria

3. Rotifers - stable; low organic levels

III. Process Design and Predicted Performance

A. Study the primary factors affecting BOD reduction and nitrification in the RBS system (Trans AD-15, AD-16).

1. Note the major significance of hydraulic loading.

2. Note the effects of BOD concentration, NH_3 concentration, temperature, flow variation and rotational speed.

B. Note typical performance regarding BOD, Suspended Solids and NH_3 reduction and sludge settleability (Trans AD-5, AD-15, AD-16).

IV. Factors Affecting Process Performance with Operational Changes

(Note: Prior Trans-re-design of units and cause-cure section of MOP No. 11)

A. Note the impact of changing water quality.

1. Increase in solids loading-flow obstruction and odor potential-improve pre-treatment.

2. Toxic substances-interfere with bio-activity-require industrial pre-treatment.

3. pH changes-decrease rate of nitrification-adjust chemically and/or industrial pre-treatment.

4. Loadings-decrease in plant performance-improve pre-treatment or alter staging and hydraulic loading.

5. Temperature drop - decrease in performance-alter hydraulic loading, heat building or housed air supply.

B. Note the impact of flow rate variations and consider equalization (Trans AD-15, AD-16).

V. RBS Plant Modifications

A. Study unit modifications e.g., staging, hydraulic loading, recycling and use of air drive system. (Trans AD-17).

B. Note the potential of chemical addition e.g., polyelectrolytes, coagulantaids, etc. to improve solid-liquid separation.

C. Review alternate pre-treatment processes to achieve pre-treatment.

1. Dissolved air flotation - oil, grease
2. Fine screening - solids
3. Aerated grit removal - grit plus DO.
4. Chemical treatment - pH, nutrients, toxics

VI. RBS System: Case Studies

A. Observe the application of the process via slide presentations of operating facilities e.g., Emmetsburg, Iowa.

B. Study the Gladstone, Michigan operation (Trans AD-18, AD-19, AD-20, AD-21)

1. Note system design - staging.
2. Note affect of pre-treatment.
3. Note process performance and temperature effects.
4. Note chemical additions.

C. Study Newell, West Virginia RBS system.

VII. RBS System: Special Applications

A. Note applications of the RBS system for

1. Sludge treatment side stream organic oxidation and nitrification - Minn. St. Paul; Chicago San. District
2. Treatment of septic tank effluents (Trans AD-24)

B. Note applications of the RBS system for treatment of industrial wastes.

1. Textile wastes - (Trans AD-23)
2. Dairy wastes e.g., Hopkinton, Fredericksburg
3. Others

EXAMINATION QUESTIONS

II3JWW Intermediate
II40WW Advanced

Note: 1. The questions for the Basic Level Module should be used as desired by the instructor and evaluating group.

2. The topical coverage for the intermediate and advanced modules is generally quite similar. The following questions are provided for use in either module. The instructor and evaluating group can make the appropriate selections.

1. RBS unit performance decreases with very low wastewater temperatures, in the 40's and low 50's (°F). This can be corrected by housing the units in a building (Emmetsburg) and heating the air or by providing ______________________________ initially in the construction of the units.

2. One of the primary advantages cited for the RBS process is its ______________________________

3. What are two pre-treatment requirements for RBS units? __________

(a) ______________________________

(b) ______________________________

T F 4. For a given RBS system-fixed media area-, you could increase the % BOD removal by decreasing the hydraulic loading that is lowering the flow rate to the disks.

5. A procedure that could be utilized to increase BOD removal in the RBS system is

a. Increase the hydraulic loading on the disks
b. Hold the pH between 6.5 to 6.8
c. Increase the number of stages
d. Increase the hydraulic loading on the final clarifier

T F 6. Wastewater temperatures between 55 and 85°F have little or no effect on BIO-SURF (RBS) process performance.

T F 7. The alkalinity of the wastewater can be reduced in RBS systems practicing nitrification.

T F 8. The optimum pH range for nitrification appears to be in the 8.0 to 9.0 range.

9. The rate of nitrification decreases with

a. decreasing DO concentration below 3.0
b. increasing BOD/NH_3 ratio in the wastewater
c. decreases in the wastewater temperature
d. All of the above

T F 10. For a given influent BOD concentration, as you increase the hydraulic loading you decrease the percent ammonia removal.

11. A white filamentous growth on the contactor midea is indicative of

a. High $CaCO_3$ levels
b. Septic wastewater and high H_2S
c. High rotation speed and lime addition

T F 12. pH control is not as critical when BOD removal is the goal. A range of 6.5 to 8.5 will not affect process efficiency.

13. What operating equipment is checked more frequently for maintenance requirements?

Answer the questions following the plant data.

Data: Flow 3.0 mgd Maximum Flow 4.8 mgd

BODs: Influent 220
Primary Effluent 155
Final Effluent 20

Final Clarifier: 70 ft. in diameter
8 ft. depth

14. Determine the per cent removal of BOD in the primary unit and the whole plant.

15. How many pounds per day of BOD is discharged to the stream?

16. Assume the total bio-disk area is 1,800,000 square feet, calculate the hydraulic loading for average flow and maximum flow conditions?

17. What would happen to plant performance if the maximum flow lasted for several days?

18. Determine the overflow rate and detention time for the final clarifier.

19. If the maximum flow rate was of short duration and occurred frequently, what could be done to modify plant operation without increasing the disk area?